EAST AFRICA HIGH COMMISSION

East African Agriculture and Forestry Research Organisation

(Incorporating the East African Agricultural Research Institute, Amani)

ANNUAL REPORT 1948

Obtainable from the Secretary, East African Agriculture and Forestry Research Organisation, P.O. Box 601, Nairobi, and from Booksellers.

Price 2/50

EAST AFRICA HIGH COMMISSION

East African Agriculture and Forestry Research Organisation

(*Incorporating the East African Agricultural Research Institute, Amani*)

ANNUAL REPORT 1948

Obtainable from the Secretary, East African Agriculture and Forestry Research Organisation, P.O. Box 601, Nairobi, and from Booksellers.

Price 2/50

CONTENTS

	PAGE
Staff List	1
Directors Report	4
Administrative Report, Amani	11
Sectional Reports	
Plant Pathology	14
Plant Physiology	16
Systematic Botany	17
Soil Chemistry	20
Colonial Development and Welfare Schemes	
Fertiliser Experiments in East Africa	26
Clove Research, Zanzibar	34
Climatic data in Relation to Agriculture	36

STAFF LIST AT 31st DECEMBER, 1948

(Including Officers of the Native Fertiliser Research Scheme and the Clove Research Scheme, Zanzibar)

DIRECTOR

B. A. Keen, D.Sc., F.Inst.P., F.R.S.
(*Appointed* 1-8-1947, *assumed duty*, 17-11-1947)

DEPUTY DIRECTOR

H. H. Storey, C.M.G., M.A., Ph.D., F.R.S.
(*Assumed duty* 11-9-1948)

RESEARCH OFFICERS

H. F. Birch, Ph.D., F.C.S.
(*Soil Chemist—proceeded on leave* 15-12-1948)

I. W. M. A. Black, Ph.D., A.I.C.T.A.
(*Soil Chemist—returned from leave* 6-4-1948)

L. R. Doughty, B.Sc. (Agric.), N.D.A.
(*in charge of Fertiliser Research Team*)

D. W. Duthie, M.A., Ph.D., F.R.I.C.
(*Soil Chemist—proceeded on leave* 3-6-1948)

J. Glover, M.Sc.
(*Plant Physiologist*)

P. J. Greenway, F.L.S.
(*Botanist—returned from leave* 14-7-1948)

R. F. W. Nichols
(*Assistant Plant Pathologist*)

F. J. Nutman, D.Sc., D.I.C.
(*Plant Physiologist, seconded as Director of Clove Research Scheme*)

P. Robinson, B.A., Dip. Stat.
(*Statistician—assumed duty* 3-11-1948)

Miss F. M. L. Sheffield, D.Sc.
(*On secondment to Clove Research Scheme from Rothamsted Experimental Station, England*).

B. Verdcourt, B.Sc.
(*Assistant Taxonomic Botanist—assumed duty at Royal Botanic Gardens, Kew*, 1-10-1948)

R. R. le G. Worsley, A.R.C.S., Ph.D.
(*Seconded to East African Veterinary Research Organisation*)

SCIENTIFIC ASSISTANTS

Miss A. L. Alexander, B.Sc.
(*Junior Chemist—assumed duty* 24-1-1948)

Mrs. R. I. Robb, B.Sc.
(*Clove Research Scheme*)

LIBRARIAN (RESEARCH)
Miss J. Ossent, M.A.
(*Assumed duty* 3-11-1948)

FIELD OFFICER
D. W. Gourlay, B.A. (Agric.)
(*Field Experimentalist Fertiliser Team—assumed duty* 17-1-1948)

FIELD ASSISTANTS
W. J. L. Arthur-Worsop
(*Fertiliser Team—assumed duty* 1-1-1948)

T. Graham
(*Fertiliser Team*)

P. H. Hosegood
(*Fertiliser Team—assumed duty* 14-1-1948)

J. D. Roberts
(*Temporary Assistant Superintendent of Plantations, Amani—assumed duty* 1-9-1948)

T. E. C. Robins
(*Clove Research Scheme*)

SECRETARY
T. Matthews, T.D.
(*Assumed duty* 7-1-1948)

PRIVATE SECRETARY TO DIRECTOR
Miss M. A. E. Vardy.

TEMPORARY CLERICAL ASSISTANTS
Miss E. M. Astell.
(*Assumed duty* 16-8-1948)

Mrs. M. Doughty
(*Fertiliser Team*)

SUPERINTENDENT OF PLANTATIONS
L. M. Fernie
(*Seconded to Tanganyika Government*)

ASSISTANT SUPERINTENDENT OF PLANTATIONS
W. B. May, F.R.H.S.
(*Seconded to Clove Research Scheme* 21-9-1948)

ENGINEER
T. V. Greenwood
(*Returned from leave* 30-10-48)

CLERK OF WORKS
L. C. Martin, M.B.E.
(*Seconded to East African Railways and Harbours*)

Under Colonial Development and Welfare Schemes administered by the Organisation:—

G. Salt, Sc.D.
(*Entomology*)

A. Walter, O.B.E.
(*Agricultural Meteorology*)

COLONIAL AGRICULTURAL SCHOLAR
E. C. Diekmahns, B.Sc.
(*Clove Research Scheme, left on appointment to Tanganyika,* 29-11-48)

REPORT BY THE DIRECTOR

1. As this is the first Annual Report of the East African Agriculture and Forestry Research Organisation (E.A.A.F.R.O.) it is appropriate to begin with a brief description of the origin and objects of this new Organisation. The account is therefore not confined to the calendar year 1948.

ORIGIN AND INITIAL DEVELOPMENTS

2. After two East African Conferences in March, 1946, and July, 1947, the Organisation was formally established — together with the East African Veterinary Research Organisation (E.A.V.R.O.)—in February, 1948, and the East African Agricultural Research Institute at Amani, Tanganyika, and its staff were formally absorbed into the new Organisation.

3. The U.K. Government agreed to provide, from Colonial Development and Welfare funds, the whole of the capital costs for a new headquarters near Nairobi and to share the recurrent costs with the territorial governments. The original estimates were prepared in July, 1947. Since then, steeply rising costs and certain under-estimates, unavoidable at the time, have necessitated a revision, and on the 31st January, 1949, a new C.D. & W. Scheme for the capital costs was made. The original development plan was divided into two phases, and £275,000 has been provided for the first phase. The number of research staff originally sanctioned was about 45, and the first phase will accommodate one-third to one-half of these. It is hoped that this section of the work will be completed by March, 1951; and that in due course, funds will be provided for the second and final phase of the original scheme.

4. It has been decided in the general interests of East Africa that the extensive herbarium at Amani shall be amalgamated with the one at the Coryndon Museum, Nairobi, and that the joint collection shall be regarded as an out-station of E.A.A.F.R.O.

5. Search for a suitable site for E.A.A.F.R.O. began in 1946. The main requirements were proximity to Nairobi, accessibility and ample room. The original choice of Kabete, in the grounds of the Kenya Veterinary Department, had many advantages, but it had to be abandoned for lack of room; the second choice, two farms, at Limuru, 20 miles from Nairobi, was a not very satisfactory compromise, and this too was abandoned. Finally an admirable position was found in the Muguga Forest Reserve only 12 miles from Nairobi. The Kenya government readily agreed to excise about 1,000 acres of the Reserve for the joint use of E.A.A.F.R.O. and E.A.V.R.O. The legal formalities are not yet (April, 1949) completed but, in anticipation, a detailed contour survey of the area was made. It has been used as the basis for an over-all development plan by the East African Railways and Harbours, whose technical departments will be in control of the construction.

6. Two boreholes have been sunk and proved; an adequate supply of good quality water is assured.

7. Detailed designs for the laboratories have been completed, and the plans for administration and library buildings are being prepared, but contracts cannot be placed until internal roads are developed and the main access road is constructed, so that the contractors can reach the site. The extensive work required to open-up the area began in March, 1949.

8. Full allowance should be made for necessary delays while decisions were being taken here, and at home, on important matters, some of which are mentioned above. At the same time, the experience of the past 18 months has clearly shown the need for a more flexible and decentralised system in minor and day-to-day matters of administrative and financial procedures. They were devised for different conditions from those that operate within a research organisation. Consequently, in their present form they may well impose an undesirably low upper limit to the speed at which the work can be completed, besides affecting the general efficiency of the Organisation when it is fully established.

OBJECTS OF THE ORGANISATION

9. The conception of a regional research centre serving a group of colonies is not new, but no full-scale trial has hitherto been made. The development of E.A.A.F.R.O. to serve Kenya, Tanganyika, Uganda and Zanzibar is therefore a pioneer venture; its successes—and mistakes — will ease the way for later Organisations in other groups of colonies. Since February, 1947, when the present Director began a preliminary tour of East Africa, numerous discussions, formal and informal, have been held and general agreement has been obtained on the functions of the Organisation in relation to the territories it serves. The agreement is based on the recognition that three stages exist between research and practice; (a) basic or fundamental research; (b) technological investigation in which the knowledge gained in stage (a) is studied within the environmental variations of East Africa; (c) introduction of the results of (b) into practice. The Organisation is concerned with stages (a) and (b) and the technical departments with stages (b) and (c). Stage (b) is therefore the vital link in which close co-operation between territorial departments and the Organisation can be built up.

10. For years past, however, the territories have been doing some basic research in commodity stations, and departmental laboratories. Clearly this should continue while the Organisation is in its early stages, and possibly beyond; the final allocation of work can only be decided by experience. Meanwhile reciprocal membership of research committees, as well as less formal contacts, have been arranged with the territories, and also with the new research stations of the Empire Cotton Growing Corporation in Uganda, and the Overseas Food Corporation in Tanganyika. These contacts, together with the East African Advisory Council for Agriculture, Animal Health and Forestry which held its inaugural meeting in January, 1949, will provide for co-ordination on an East African basis of fundamental and technological researches.

11. Animal husbandry research is necessarily the concern of both agricultural and veterinary scientists: neither can cover the whole

field alone. For this reason, E.A.A.F.R.O. and E.A.V.R.O. decided to create at Muguga a joint section for Animal Husbandry. The great advantages,—and, indeed, the necessity—of unifying the research in this subject far outweighs any administrative and accountancy problems that might arise when two Organisations have one section in common. The fact that the Headquarters of the two Organisations will adjoin each other also makes possible the sharing of several other activities in efficient and economical ways. The general analysis laboratories, and the statistical section will serve both Organisations. There will be one library, store, workshop, etc., and transport can be pooled. The resulting economics in staff will enable a specially qualified officer to be recruited for each section at less cost than the combined salaries for a duplicated but less qualified staff.

SCIENTIFIC WORK OF THE ORGANISATION

12. During the year several members of the small Amani staff had, by regulation, to take a portion of their heavy war-time accumulations of home leave, and this circumstance has affected the work. Besides the investigations at Amani, there are two major C.D. & W. research schemes and two smaller ones under the general scientific supervision of the Director. The major schemes were set up as a matter of urgency before E.A.A.F.R.O. was established, and they will be absorbed in the Organisation in due course. They deal with response to fertilisers and manures in East Africa, and with the "sudden death" disease of clove trees in Zanzibar, and Pemba.

13. Each scheme is in charge of an officer seconded from the Amani staff. Separate reports of these schemes and of the Amani work, written by the officers concerned, are appended to this Report. Their salient points are discussed below against the background of the broad agricultural problems of East Africa, and the priorities that have been adopted for the expanding work of the Organisation.

14. One over-riding factor which is not even yet fully realised is that our knowledge of agricultural science and the sound practice deriving therefrom were built up almost entirely for temperate climates, enjoying a well-distributed rainfall. The assumption that all these practices would also be correct for the tropics and sub-tropics is unwarranted because of the very different environmental conditions. To mention only one factor, the dead season in the temperate zone is the winter, when the soil is cold and wet—the dead season in the tropics—excluding tropical rain-forest and perennial irrigation areas—is the summer, when the soil is hot and dry. There are other differences of varying degree from temperate soils: in soil behaviour, the organic matter status, moisture relationships and inherent soil fertility. These, in turn will influence the soil structure and hence its erodibility, the growth and nutrition of plants, and the all-important African problem of devising better pastoral and mixed farming systems.

SOIL FERTILITY

15. The above considerations confer high priority on investigations into the fertility status of our soils. Both basic and technological investigations are in progress. The fertiliser team under

Mr. Doughty laid out and harvested by sampling methods, a large number of field experiments in African areas. A separate scheme under the Kenya Department of Agriculture in collaboration with Imperial Chemical Industries undertook experiments on European farms in the Kenya Highlands. The two Schemes are closely co-ordinated and share a common headquarters, and both are under the general scientific control of the Director of E.A.A.F.R.O. The field work in both schemes has been done under great difficulties and the enthusiasm of all concerned deserves to be recorded. Much has been learned in this initial year about the administrative and technical problems of conducting accurate field experiments widely scattered over East Africa, when only a small number of supervising staff is available. Much has also been learned on co-operation schemes of work in the technological sphere.

FIELD TRIALS (*i*) *Phosphate Requirements*

16. Special attention is being given to phosphate because of its intrinsic importance and the possibility that the large rock-phosphate deposits in Uganda can be exploited. The ground rock phosphate is, by conventional laboratory analyses very poor in available phosphate. A preliminary statistical examination of the field results shows that the increase in yield is generally small and in some instances a decrease is obtained. There is also a suggestion that the double dressings produce a lower response than the single dressing. Earlier investigations by the East African Industrial Research Board on methods of increasing its phosphate availability led to the production of a "soda-phosphate" by calcining the ground rock and with imported super-phosphate which is already used in quantity in the Kenya Highlands. Preliminary statistical examination shows that soda-phosphate and super-phosphate give, in general, progressive increases in yield with increasing dressings. In certain districts, super-phosphate, weight for weight, is considerably more effective than soda-phosphate but soda-phosphate is considerably given increase in yield, the cost of the larger dressing of soda-phosphate cheaper and at present prices the tentative conclusion is that for a needed in those areas would be approximately the same as that for super-phosphate. In other areas where smaller dressings of soda-phosphate are needed for a given yield increase, the price advantage would be in its favour. Clearly, further years of trials are needed to assess the effects of season, soil type and the relative response of various crops. The bulk of the past seasons experiments have been done on grain crops: wheat, maize and millets. As would be expected. they show progressively higher responses in the wettest districts (average rainfall over 50″) as compared with medium districts (40″—50″) and dry ones (under 40″). Maize, however, responds equally well in both the medium and the wet districts.

FIELD TRIALS

(*i*) *Phosphate Requirements*

17. The responses to nitrogen, potash and lime were, in general, smaller and less regular than to phosphate, and they included a number of reductions in yield. There are indications, as with phosphate, that soil type is an important factor in the response to nutrients; but more knowledge on inherent soil fertility and soil genesis is needed before the connection can be exploited.

LABORATORY INVESTIGATIONS

18. Samples of soil and produce from the plot sites are being systematically examined by Dr. Birch and Dr. Black. The long range basic research problem is to study the inherent fertility status of tropical soils. The immediate technological problem is to see how far the figures from existing methods of soil analysis tally with the field results of manuring and to devise suitable modifications of the laboratory methods for tropical soils. Dr. Birch is attacking first the problem of phosphate determination. He is investigating a number of methods including those that use more than one extracting agent, thus dividing the soil phosphate into two or three fractions, to see how far the correlations with phosphate in the plant, and with plant yield can be improved.

19. Dr. Black has installed a spectrograph and is now engaged on the determination of exchangeable bases in the large number of samples received from the fertiliser experiment sites.

20. Mr. Glover is studying plant nutrition in sand cultures. The expectation is that this work will complement the soil and field investigations with the fundamental and technological problems of fertility. Maize is being used and the work will be extended to other crops when facilities and staff permit. As would be expected the experiments have shown the importance to plant growth of a correct balance of nitrogen and phosphate. The uptake of nitrogen or phosphate from the solutions depends on the amount of the other nutrient, so that plants supplied with excess nitrogen for balance, show signs of phosphate deficiency and are smaller than those given the same amount of phosphate with less nitrogen. The balance itself depends on environmental and other conditions which will be further studied in due course and linked up with the field experiments. Observations on the latter were systematically taken during growth, by simple scoring methods, and in addition a number of micro-plot experiments were done. These showed a strong inter-action between nitrogen and phosphate, often to a late stage of growth, but in the harvest figures the interaction had nearly or completely disappeared. It is a common experience, especially in cultivation experiments in temperate climates, to find striking correlations between the type of cultivation and vigour of early growth; these too mostly disappear by harvest time. It is important to know, for our soil and climatic conditions, which of the early signs of manurial (and cultivation) responses are significant in relation to yields, and the plant nutrition experiments and the field growth observations will be directed to that end.

PROBLEMS OF PLANT DISEASE

21. The only lines of work in progress at present deal with the "sudden death" of cloves in Zanzibar and Pemba; virus diseases of cassava; and virus diseases of groundnuts. A study of the threatening canker disease of cupressus will shortly begin by Dr. Rudd Jones who will be seconded to the Kenya Forest Department for this purpose.

(i) *Sudden Death of Cloves*

22. Dr. Nutman was seconded from Amani in November, 1946, to take charge of this C.D. & W. Scheme. Laboratories had to be built

and equipped, and staff collected. By May, 1948, the unavoidable delays and difficulties had been surmounted, and since that date marked progress has been made.

23. Sudden Death has not yet been identified, but the Clove Research team has produced strong circumstantial evidence that it is a virus disease, and that a likely vestor is a scale insect (*Coccus hesperidum*) tended by the red tree ant in their nests in the foliage. As its name implies, the difficulty of studying the disease is increased by short intervals between the appearance of obvious symptoms and death. However, during the long-range research work on the physiology of the clove, preliminary symptoms associated with slight chlorosis have now been recognised both in the field and laboratory, and suspect trees can now be identified with some certainty well before the obvious final symptoms appear. Direct experiments to show that the scale insect from a suspect clove can infect a healthy one are very difficult to make because of the habits of the insect. The standard transmission proof of a virus disease, the infection of a healthy stock by a diseased graft—has not yet been achieved, owing to the extreme difficulty of obtaining true union at the graft. However, encouraging progress has been made in both these lines of work: there is reasonable expectation that proof or disproof of the virus hypothesis and of the complicity of scale insect will be obtained in the near future.

24. An indication of the special difficulties confronting the research team is given by the results to date of Dr. Sheffield's extensive histological and anatomical investigations on the clove. Abnormalities characteristic of a pathological condition were found in diseased cloves. But they were also found in healthy cloves although they were less intense and their onset was delayed. Taken alone this evidence could suggest that continued adverse conditions, and not disease, are responsible for Sudden Death.

25. Against this must be set the detailed examination that has been made of the present situation and of past records, in relation to the incidence, manner and rate of spread of Sudden Death. These studies show beyond any reasonable doubt that Sudden Death is due to some pathogen; that in Zanzibar, where half the trees are now dead, it has increased to an epidemic that is now practically beyond control; and that Pemba with its 500 separate and mostly small outbreaks is in an earlier phase of attack, and is now in grave danger of entering, in turn, into the epidemic stage.

26. The threat is serious enough to warrant the trial of vigorous control measures in Pemba even though our knowledge of the disease is incomplete. The proposals involve the eradication and destruction of suspect trees and a surrounding belt of apparently healthy ones together with their insect inhabitants. A special memorandum on this subject was prepared. It has been considered and endorsed by an expert Mission sent from England, who made a detailed study on the spot.

(ii) Virus diseases of ground-nuts

27. Since his recent return to East Africa Dr. Storey has begun fundamental work, with special reference to the mechanism of virus

transmission. The work is of East African significance, and has special importance for the Overseas Food Corporation, whose Scientific Section is providing technological collaboration.

(iii) Virus diseases of cassava

28. A review of the ten years work was given in the 1947 report, of Amani, so little needs to be added here. Mr. Nichols is temporarily discontinuing the production of new clones and is concentrating on testing the agronomic quality and resistance to disease of the large number already produced. These results should be available by the middle of 1951. There are very reasonable hopes that the back-crossed inter-specific hybrids will show that they have regained yield and quality factors without losing their high resistance to mosaic and brown streak, the two common virus diseases of cassava in East Africa.

(iv) Insect pests

29. It has not yet been possible to recruit any entomologists for the E.A.A.F.R.O. staff. However, valuable assistance in defining the problems for research has been given by Dr. Salt who spent nine months in East Africa by arrangement with the Colonial Office. His report and recommendations are now being completed and the account of actions taken thereon will be given in the next Annual Report. During his visit Dr. Salt also assisted the territorial departments and the Overseas Food Corporation on a number of matters.

SYSTEMATIC BOTANY

3. The activities of the Herbarium and the associated field work are described in Mr. Greenway's report. In addition, he has greatly assisted in the publication of the late Mr. Gillman's vegetation map of Tanganyika and the accompanying text. He has co-operated with Mr. Eggeling, Conservator of Forests, Uganda, and Mr. Edwards, Pasture Research Office, Kenya Agricultural Department, in producing a preliminary map of the vegetation zones of East Africa.

SOIL MOISTURE

31. In the climatic conditions of East Africa water is in general a limiting factor in both arable and animal husbandry. Soil moisture, however, is only one term in the general hydrological equation connecting rainfall with evaporation, transpiration, run-off and percolation, and the values of some of these terms, notably evaporation and transpiration, are very difficult to assess as they are affected by changes in the soil moisture. In recent years considerable progress has been made in the study of this problem for temperate climate conditions and steps have been taken to extend the work to our sub-tropical conditions.

32. Moisture exchange between soil and air is largely dependent upon the amount of the incoming radiation. Radiation measurements, however, are taken at very few places, so the initial problem is to infer the amount of radiation from the simple air temperature records taken at numerous meteorological stations. This investigation is well

in hand. It is being undertaken by Mr. A. Walter, formerly Director of the East African Meteorological Service, through a C.D. & W. Research Scheme. The next step will be to assess the effect of radiation on the terms of the hydrological equation. There are two directions in which this information is urgently needed. One is to assess the accession to the underground water reserves over a given catchment area; this knowledge is essential if development plans are to have a sound basis. The Research Organisation is in close touch with experimental work being done jointly by the Kenya Department of Agriculture and the Public Works Department, and a specialist committee on Water Utilisation by Vegetation has been set up by the East African Advisory Council on Agriculture to deal with developments in due course. The other direction is, ultimately, to delimit various climatic zones within which specific systems of agriculture will be, or not be, feasible.

ADMINISTRATION AND STAFF

33. This section of the Report can be brief because the centre of the Organisation is, for the present, at Amani, where it must remain until it can be removed to the new Headquarters. Reference can be made to the administrative report for Amani which follows below, and which describes some of the problems of the past year.

34. The restricted housing accommodation at Amani has controlled the possible accession of new staff; in any case, demand has far exceeded supply. To-date, however, the following new appointments have been made to the scientific staff:—Deputy Director (Dr. H. H. Storey, C.M.G., F.R.S.), Mycologist, Statistician, Assistant Taxonomic Botanist, four women graduates as scientific assistants to the administrative staff:—Secretary, Assistant Secretary, Librarian, Storekeeper. The two latter will, in due course, be in charge of the common library and common store for E.A.A.F.R.O. and E.A.V.R.O. at Muguga. A Farm Manager for the joint Animal Husbandry section will shortly be appointed.

35. Dr. Keen and Dr. Duthie were delegates to the Conference on Tropical and sub-Tropical Soils organised by the Commonwealth Bureau of Soil Science in England, June, 1948. This conference was preceded by a Soils Discussion Group meeting of East African delegates and others, held under the auspices of E.A.A.F.R.O. in April, 1948, in Nairobi.

36. Dr. Keen attended, as a Colonial Office delegate, the Royal Society Conference on Scientific Information held in England, June/July, 1948. He also attended, as leader of the East African delegation, the Conference on Soil Conservation held in the Belgian Congo, November, 1948.

ADMINISTRATIVE REPORT—Amani.
Dr. H. H. Storey, C.M.G., F.R.S.

37. The Amani station was formally absorbed into the E.A.A.F.R.O. on 1st January, 1948. It has remained, and until new buildings are available at Muguga will continue to remain, the main

research centre of the Organisation. Its laboratories are capable of accommodating a larger research staff than at present; but a limit to expansion is imposed by housing, which with the small staff-increases over the year is now nearly fully occupied. At this stage any considerable new building at Amani could not be contemplated; but by taking into permanent use the house hitherto retained as a guest house and by certain inexpensive modifications to other buildings it will be possible to add slightly to the European accommodation. For Asians and Africans it has been necessary to face a minimum amount of new building as the only means for accommodating staff that must inevitably remain at Amani for at least two or three years.

38. Amani has also become the administrative and accounting headquarters for the Organisation under the general direction of Dr. B. A. Keen from Nairobi. For the administrative staff 1948 has been a difficult year. Staff largely unfamiliar with Amani's past was called upon to cope with the complications of the change-over to administration under the E.A. High Commission and to handle the many problems following from the initial expansion of the Research Organisation. Difficulties were much increased by the long distance separating Amani from Nairobi, precluding personal contacts, except through occasional visits, between the Secretary on the one hand and the Director of the Organisation and the Chief Accounting Officer of the High Commission on the other. There is a clear need to move the central administrative and accountancy office to Nairobi at the earliest possible date.

39. For the first half of the year the station was in the charge of Dr. D. W. Duthie; thereafter for varying periods in the charge of Dr. H. F. Birch, Mr. P. J. Greenway and Dr. H. H. Storey, who arrived in October. Mr. T. Matthews was appointed Secretary at the beginning of the year, and the Assistant Secretary, Mr. S. G. Walter, assumed duty only after the year was ended.

40. The Amani station has always been an almost completely self-contained community, providing itself with services without outside help. Thus the station Engineer is responsible for the construction of new buildings and the maintenance of old ones, for the operation of the power supply from the hydro-electric plant, for water supply, gas supply to laboratories, operation and maintenance of motor transport and the running of mechanical and carpenters' workshops. In addition he undertakes, on behalf of the Tanganyika Public Works Department, maintenance of the twenty-three miles of road between Muhesa and Amani. A further special task during 1948 has been to organise timber felling and sawing, which has resulted in the collection into store of some 3,500 cubic feet of Mvule (*Chlorophora excelsa*) timber, to be used later on the construction of the new headquarters at Muguga.

41. For some twenty years Mr. T. V. Greenwood has been in charge of these activities and under his guidance much of Amani as it now is has been built up. During a period of his leave from June to November, 1948, it became necessary to call on a research officer, Mr. R. F. W. Nichols, to take his place. Mr. Nichols performed this unfamiliar task with great credit, though inevitably at the expense of his work on cassava breeding.

42. The work of the Superintendent of Plantations includes the maintenance of the plantations and nurseries on the Amani estate, reaping and preparation of saleable crops, distribution of seeds and plants of economic and ornamental species, the care of the cattle herd and general supervision of the African villages on the estate. During the year the substantive Superintendent of Plantations remained seconded to the Tanganyika Department of Agriculture; and in September, 1948, Mr. W. B. May, the Assistant Superintendent, was seconded to the Clove Research Scheme in Zanzibar. For some two months the station was without a European Superintendent; but in November the duties were taken over by Mr. J. D. Roberts, previously a Field Assistant in the Native Fertilizer Scheme. Mr. P. J. Greenway, the Botanist of the station, supervised the work of African plantation staff during periods when no Superintendent was available.

43. During the year the plantations were kept on a minimum maintenance basis, but even so with difficulty owing to shortage of labour which has tended to move away to the commercial plantations now developing around Amani. The Nursery distributed about 180 lots of seeds, 1,300 plants, 1,000 Derris cuttings and 200 kg. of ginger roots for planting. 320 kg. of Areca nuts were reaped and sold.

44. A further responsibility of the Superintendent of Plantations has been the management of the Kwamkoro Estate, which after coming under the control of the Director of Cinchona Research in 1945 reverted again to Amani in 1947 on the termination of the Cinchona Scheme. The development of the estate had started in 1935 partly as an experiment in plantation agriculture in the Usambara Mountains and partly as a source of revenue. In fact, as noted in later reports of the East African Agricultural Research Institute, the experimental purpose of the scheme has been fulfilled, and Kwamkoro is now run mainly as a commercial enterprise. Apart from small areas occupied by the Plant Pathologist's cassava maintenance plots, the estate has ceased to be of interest to a research establishment, and has in fact become a needless burden during periods, as in 1948, when Amani plantation supervisory staff has been short or lacking. In November, we were fortunate to secure the temporary services, as Manager, of Mr. T. A. Baldock, while on a six-mouth visit; he was able greatly to improve the efficiency of management which had suffered during a period when little supervision had been possible from Amani. Early in 1949, however, management will revert to Amani. It is satisfactory to be able to report a provisional agreement that Amani's responsibility for Kwamkoro will cease at the end of 1949, when the Government of Tanganyika is expected to resume possession.

45. Production during the year from Kwamkoro Estate was 11,000 kg. Cinchona bark, 2,000 kg. Tung nuts, and 500 kg. Robusta Coffee; and about a thousand gallons of milk were sold to the Amani staff.

46. The houses of the Central Quarantine Station, which fell into disrepair during the war, are now partly serviceable. Eleven varieties of sugar cane are in process of quarantine, and thirteen miscellaneous ornamental plants have been passed through.

47. Editorship of the East African Agricultural Journal has remained during the year a responsibility of Amani. The bulk of the work concerned has fallen on Mr. P. J. Greenway, who has carried it through with conspicuous success in addition to his work as botanist. Arrangements have been made to transfer the editorship to Nairobi under a re-organisation proposed to and accepted by the E.A. Advisory Council for Agriculture, Animal Health and Forestry.

48. In the hands of the Librarian, Miss J. Ossent, appointed on the 3rd November, 1948, the re-organisation of the Library is well advanced.

SECTION OF PLANT PATHOLOGY

Dr. H. H. Storey, C.M.G., F.R.S., *Deputy Director*
Mr. R. F. W. Nichols, *Plant Pathologist*

VIRUS DISEASES OF CASSAVA—*R. F. W. Nichols*

49. Despite my deflection to other duties for five months of the year and periods of ill-health, breeding and testing of hybrid clones has continued on the lines set out in my report for 1947. But on account of these interferences, I ended the year with my normal schedule two months in arrears. Furthermore for some years now I have been working single handed and investigational work on plant viruses has been severely hampered by the amount of field work that has fallen on me owing to staff shortages. This has been increasing from year to year; but happily this state of affairs is now being remedied and in future I shall be able to devote more time to problems which await investigation.

50. Work continued throughout the year on clearing a further area of land on Kwamkoro Estate for use in propagating and multiplying the large number of hybrid cassava seedlings raised at Amani. About 12 acres have been cleared of quinine and grevillea trees. In the absence of mechanical equipment of any kind, this work had to be done manually and it proved exceedingly arduous. Removing the grevillea logs from the site is in itself a major operation which is hampered by shortage of transport; 1,000 or more logs still await removal to the saw-mill. The area of land cleared will be sufficient for the needs of the coming year but it may be necessary to clear a further area the following year. There is the ever present danger of severe out-breaks of Armillaria root disease occurring on these newly cleared areas, but this is a risk which has to be taken.

51. On the purpose and procedure of cassava breeding I have little to add to my report submitted for 1947. The programme is being continued on the same lines. During the year under review over 7,000 flowers were hand-pollinated and these yielded 4,400 seeds which will be grown and put into a preliminary field trial for disease resistance during the coming year. Most of these seeds are the progency of second back-crosses to cassava from inter-specific hybrid of the species listed in previous reports.

52. The yearly field trials on land at the Sisal Experimental Station, Ngomeni, were harvested between July and September. Of

the 240 clones undergoing replicated trials for resistance to mosaic and brown streak only three completely resisted infection by mosaic. Two of these were mildly affected by brown streak, the third being unaffected by either disease. One of them gave a good yield but the roots were very uneven in shape and on this account probably would not be acceptable to growers. Unfortunately the true parentage of these hybrids is unknown because they were up-rooted by wild pig in the nursery bed, while still in the seedling stage, and all the numbers became confused.

53. Final records of the 526 clones in the preliminary trials resulted in 57 clones being retained for further investigation. These were planted in replicated trials in October, 1948. In addition 1,620 clones from the 1947 breeding season were planted out in preliminary trials. The current field trials occupy an area of a little over five acres; this land has not previously carried cassava. The land used during the preceeding three years has been put down to a three-year fallow with elephant grass (*Pennisetum* sp) as a cover.

54. A stage has now been reached in this breeding work where, considering the available facilities, it seems desirable to discontinue temporarily production of new clones until the many clones on hand have been tested and their worth assessed. Preliminary tests of a proportion of these will be completed by the middle of 1949 and the rest by the middle of 1950. The replicated trials following on from these will not be terminated until the middle of 1951. By that time, if reasonable hopes are fulfilled, there should be several clones in existence of good agronomic ouality and with high disease resistance, and so fit for trial by Agricultural Departments all over East Africa.

55. Within the Ceara group of inter-specific hybirds, there is little doubt that the third back-cross generation will produce clones with "tubers" indistinguishable from ordinary cassava. With the *Manihot Dichotoma* group it is probable that back-crossing will have to be carried to a fourth or even fifth generation in order to secure the desired agronomic qualities. The outstanding fact at the present stage is that high disease resistance has been secured in the second back-cross generations; if this can be maintained to the point where the desired agronomic qualities are restored in succeeding generations then the two virus diseases should cease to be a limiting factor in the cultivation of cassava.

VIRUS DISEASES OF GROUNDNUTS—H. H. Storey

56. Research on virus diseases of groundnuts, particularly the rosette disease prevalent in many parts of Africa, is being planned with the Scientific Section of the Overseas Food Corporation centred on Kongwa, Tanganyika. Agreement was reached that the East African Agriculture and Forestry Research Organisation would study the more basic problems and particularly those concerning the transmission of the virus. The few months since my return to East Africa have been devoted to planning, the assembly of materials and the development of techniques for this work. With the appointment of an assistant early in 1949, I expect that research will make rapid progress. The work is of evident importance, not only because rosette disease constitutes a serious hazard in the developments by the Overseas Food Corporation but also because of its effects on groundnut production generally in Africa.

SECTION OP FLANT PHYSIOLOGY

J. Glover, M.Sc.

57. During the past year I continued to investigate the nutrition of young maize in sand culture. My object was to study the effect of different levels of Nitrogen (N), Phosphorous (P) and Potash (K), and their interactions, on the fresh and dry top and root weights and top/root ratios, on the water content of the plant per unit dry weight (succulence), and on the uptake of ions, mainly nitrate and phosphate (PO_4), from the nutrient solutions.

58. All experiments were of 3^3 or 3^4 factorial design. The nutrient solutions, which were applied every alternate day, were chosen to cover much of the range of concentrations of N, P and K, such as are reported to occur in soil solution. All other elements were supplied at constant and adequate levels. The uptake of N was measured every alternate day and the plants were harvested 28 days after emergence above the surface of the sand.

59. The results showed that N and P appeared to play a dominant rôle in increasing the weight of the young plant, the top/root ratios and the amount of nitrate the plant consumed. They also appeared to be important in increasing succulence, but here K also played a part. In general the effect of K over a wide range of concentrations was comparatively unimportant. Unless the NP balance was satisfied the plants grew indifferently. For example, if N was present in excess of the amount required to balance P, then hidden or visible symptoms of phosphate deficiency were produced and the plants were small, even though the same amount of P when combined with lower levels of N was sufficient for the growth of larger healthy plants. When unbalance occurs in this direction, increasing the supply of N only increases the harmful effects, but the addition of P to restore the balance produces marked increases in yield (weight). Likewise, when P is in excess relative to N, additional P has no effect in increasing yield but additional N gives a very marked response.

60. The uptake of N from solutions, as might be expected, also appeared to be governed by the NP balance. Excessive N relative to P greatly reduces the uptake of N; while excessive P relative to N does not produce any marked increase in uptake above that of plants grown in solution in which the same amount of N is balanced by lower levels of P.

61. As far as succulence is concerned, it would seem that the succulence of tops is mainly governed by the NP balance as above. However when this is satisfied, increasing K, particularly at the lower levels, further increases succulence. The succulence of roots is also apparently modified by the NP balance but not markedly so.

62. The NP balance does not seem to be an exact ratio of one element to the other, for it appears to be modified by enviromental conditions, the concentration and total amount of the solutions and possibly the different levels of the other elements. It needs further investigation. NK, NCa and PK interactions were also observed, but they were very slight by comparison with that of N with P. They too need further study.

63. This preliminary work appears to show the importance of P in controlling the growth of the young plant, particularly since a small increase in P at low levels apparently makes available to the plant much greater amounts of N. These effects have been noted with plants of similar age in the "microplot" field trials of the East African Fertiliser Schemes.

64. Plants are now being grown through to maturity in similar solutions and their N and P uptake is being measured every alternate day as before. Mr. Noronha has been appointed as my assistant to help with the numerous analyses.

SECTION OF SYSTEMATIC BOTANY

Mr. P. J. Greenway, F.L.S., *Botanist*
Mr. B. Verdcourt, B.SC., *Assistant Botanist*
(*Appointed October,* 1948)

65. During 1948 work in this section has been somewhat interrupted as I was on postwar leave to the U.K. from April to mid July. On my return I was Officer-in-Charge of Amani till the end of October ; in addition I was Editor of the *E.A. Agricultural Journal* from July onwards. Mr. B. Verdcourt started in October a year's training in the Herbarium of the Royal Botanic Gardens, Kew, being engaged on verifying the botanical identities of the very many collections of plants sent from Amani to Kew, and on taxonomic studies of the Tropical African members of the general *Cuscuta* and *Otiophora.*

VISITORS

66. The following visited Amani for the purpose of study in the Amani Herbarium :—Mr. A. Bogdan, Pasture Research Officer, Department of Agriculture, Kenya, on the Gramineæ and the weed flora of Kenya ; Mr. P. R. O. Bally, Botanist, Coryndon Memorial Museum, Nairobi, on the Euphorbias of East Africa and the flora of Kenya ; Mr. Olle Hedberg, Institute of Systematic Botany, Uppsala, Sweden, on the flora of the East African mountains.

THE HERBARIUM

67. During the year, 66 accessions of botanical material totalling 1,534 specimens were received for indentification. Of these the more important collections were from :—

Uganda :—Agricultural Department (J. W. Purseglove, 174). Forestry Department (Messrs. Dale, 61 ; Dawkins, 38 ; and others, 51).

Kenya:—Agricultural Department (A. Bogdan, 23 ; D. C. Edwards, 13). Coryndon Memorial Museum (P. R. O. Bally, 14). Miscellaneous private collectors, 92 specimens.

Tanganyika :—Agricultural Department (Messrs. Childs, 193 [grasses]; Wallace, 31; and others, 10). Forest Department, 304. Administration and Police, 29. Overseas Food Corporation (Messrs. Anderson, 28 ; and Evans, 21). Miscellaneous private collectors, 87 specimens.

Belgian Congo :—F. L. Hendrickx, Institut Nat. L'Etude Agric., 134 specimens.

South Africa :—Rev. J. Gerstner, 4 *Strophanthus* spp.

68. One hundred and sixty-four named duplicate specimens were distributed to various institutions in different parts of the world. Leaf and bark material of *Mitragyna rubrostipulacea* (K. Schum.) Havil., supplied for chemical investigation to Prof. J. W. Cook, The University, Glasgow, at the request of the Colonial Products Research Council, was found to contain the active principle mitraphylline in equal amounts both in the bark and leaves.

69. In exchange, one hundred and forty-seven named specimens, mostly East African, were received from the Royal Botanic Gardens, Kew.

70. Five hundred and twenty-four sheets were loaned for study to the following:— Prof. C. E. B. Bremekamp, Botanisch Museum, Utrecht, Holland, 45 sheets Rubiaceæ; the Royal Botanic Gardens, Kew, 431 sheets of German collected ferns, *Crassocephalum*, *Gynura*. *Senecio*, etc.; Dr. K. Suessenguth, Botanischen Staatssammlung, Munchen, Germany, 48 critical Amaranthaceae for identification.

71. Determinations on various plants totalled 783. Notes and memoranda were supplied on such items as Uganda trees, timber trees of possible economic importance, and the identification of native medicinal and poisonous plants, including the distribution of certain species of *Strophanthus* in East Africa. Other work included the naming of collections of plants from Mts. Elgon and Kilimanjaro, ferns from Kenya, pasture plants from Tanganyika and Kenya; and the identification of the host plants of *Hilda patruellis* for the Overseas Food Corporation and the naming of flower sketches.

72. Notes were supplied on the Bambusae, both wild and cultivated in East Africa; on the distribution of all the known species of Ficus in Uganda; on the distribution of all the known species of Clover found in Tanganyika; a list of all gall Acacias recorded in East Africa and a list with the distribution of all genera of palms found in a wild state in East Africa.

73. During the work of naming collections, a further 19 type specimens were recorded in the Herbarium and the following new species were described from the Amani Herbarium.

New Species

74. *Mansonia diatomanthera* Brenan (Sterculiaceæ) in Hook. Ic.Pl, t. 3451. Yussif bin Mohamedi 8626 ! type.

Pavetta hochstetteri Brem. var. *graciliflora* Brem. Rubiaceæ in *Fedde Repert.* 47; 95 (1939). Rounce 251 ! type.

Pavetta petraea Brem. in *Fedde Repert.* 47; 93 (1949). Greenway 4326 ! type.

Platypterocarpus tanganyikensis Dunkley & Brenan (Celastraceæ) in *Kew Bull.* 1948. P.47 Fletcher H56/37; H66/36 ! type; Greenway 4617 !

Protea angustimarginata Hauman (Proteaceæ) in *Bull. Jard. Bot. L'Etat Brux.* 19. 56 (1948). Greenway 7685 ! type.

Protea heckmanniana Engl. var. *angustifolia* Hauman in *Bull. Jard. Bot. L'Etat Brux.* 19. 56 (1948). Michelmore 1076 ! type.

Protea ramosa Hauman in *Bull. Jard. Bot. L'Etat Brux.* 19. 54 (1948). Greenway 7730 ! type, 7753 ! and 7667 !

Tridactyle cruciformis Summerhayes (Orchidaceæ) in *Kew Bull.* 1948. p.293. Moreau 17 ! type ; 116 !

Tridactyle inflata Summerhayes in *Kew Bull.* 1948. p.281. Moreau 326 ! type.

75. These additional records bring the total number of known iso-types in the Amani Herbarium up to four hundred and forty-eight.

76. The new species of *Mansonia* is of particular phyto-geographical interest as the genus was first described in 1905 from Southern Burma near the border of Siam. Since that date two other species have been recorded, both from West Africa.

77. *Platypterocarpus*, a new endemic genus, is another phyto-geographical and taxonomic puzzle, since its nearest affinity seems to be with that of *Wimmeria* Schlechtend, a Mexican and Central American genus.

78. During the year 1,994 specimens were filed in the Herbarium, making a total of over 58,300 named sheets, of which there are over 7,200 grass specimens for study.

79. Whilst on home leave, I spent most of my time in the Herbarium, Royal Botanic Gardens, Kew, working on a collection of over one hundred and eighty plants that I made in 1946 on Mount Hanang, Tanganyika. I am writing two papers on the flora of this isolated extinct volcano, one on the ecology of its plants, the other on their geographical distribution.

FIELD WORK

80. Little time was available for field work, but a visit was made to Uganda towards the end of December for the purpose of conferring with Dr. W. J. Eggeling, Conservator of Forests, Uganda, and Mr. D. C. Edwards, Senior Agricultural Officer (Pasture Research), Department of Agriculture, Kenya, and with them drawing a map showing the main ecological zones of East African vegetation and indicating thereon the existing crop and research stations of all technical departments of East Africa, for presentation to the East African Advisory Council on Agriculture, Animal Industry and Forestry.

Publications

81. The Papaw or Papaya. *E. African Agric. Journ.* 13, 4, 228-233 (1948). Review : Five Hundred Varieties of Herbage and Fodder Plants. *E. African Agric. Journ.* 14, 2, 99 (1948).

SECTION OF SOIL CHEMISTRY

Staff

D. W. Duthie, PH.D.
H. F. Birch, PH.D.
I. A. Black, PH.D.
Miss A. Alexander, B.SC.

SOIL AND PLANT ANALYSIS—D. W. Duthie

82. When preliminary research plans were drawn up for the East African Agriculture and Forestry Research Organisation it was evident that a large number of soil and plant analyses would be required, and since the East African Agricultural Research Institute had no analytical staff at Amani the formation of an analytical unit was a matter of great urgency. Consequently it was decided to recruit women graduates in chemistry, who could quickly learn the technique of soil and plant analysis, and to postpone the training of African analytical assistant until the laboratory work is transferred to the new headquarters in Kenya.

83. It is anticipated that exchangeable bases in soils will be determined by spectrographic methods, but even so the mechanical analyses and the estimations of pH, nitrogen, phosphate, calcium, soluble salts and plant and tissue analyses, will require a large analytical laboratory.

84. Miss A. L. Alexander, the first of the Junior Chemists, took up her post in January, 1948, and first spent a few months learning the technique of soil analysis and in comparing some recently published methods with those which had been used in previous years. The development of semi-micro colorimetric methods gives promise of speeding up soil analysis, but the application of these new methods to tropical soils cannot be accepted without thorough test.

85. During the remainder of the year the majority of soil samples came from the Fertiliser Experiments Scheme, and 220 of these were examined analytically. In addition, 87 soils were received from other sources for miscellaneous analyses. Although it had not been intended to undertake plant analysis at this stage, it was found possible to assist the Plant Pathology section in their work on cassava by analysing the roots of some of their most promising crosses for protein, fibre and hydrocyanic acid.

SPECTROGRAPHIC WORK—I. A. Black

86. The spectrographic work during the year has consisted largely in setting up the equipment for the routine determination of exchangeable bases in soils by the Lundegardh flame method.

87. The Hilger Medium Spectrograph, microphotometer and accessories arrived at the end of June. The equipment, which is the property of the Scott Agricultural Laboratories, Nairobi, had had considerable use for a variety of purposes prior to its arrival but, after some adjustment, was all found to be in good working order. Considerable time was devoted to the final adjustment of the apparatus and difficulty was experienced in obtaining photographic plates on suffi-

ciently thin glass to suit the curved plate holder of the No. 488 spectrograph. The latter difficulty was overcome by fitting modified guides in the plate holder.

88. By the end of the year the spectrographic method of determining exchangeable bases in soils had been thoroughly examined and had been found satisfactory when applied to solutions of known composition and when used with soils which had previously been analysed by chemical methods. In addition, several methods of extracting the soils had been compared and the most convenient selected for routine use. The standard errors for determining calcium, potassium, manganese and sodium in solution had been reduced to less than 5% while the S.E. for magnesium was about 7%. The standard errors for determining these elements in soils (which include subsampling and chemical preparation errors) were naturally higher and amounted to about 10%.

89. By the end of the year, the spectrographic method for determining exchangeable bases in soils was considered to be in satisfactory working order and ready to be applied to the large number of soil samples from the Fertiliser Experiments Scheme which are awaiting examination.

SURVEY OF SISAL DISEASES—I. A. Black

90. This work was undertaken with a view to discovering which of the known sisal diseases could be attributed to mineral deficiencies and to suggesting the most promising lines for future investigation. During the course of the work, many sisal estates in Tanga Province were visited in the company of Mr. G. W. Lock, O.B.E., of the Sisal Research Station, Ngomeni, and we also made a ten days' tour in the Southern Province. Samples of sisal leaves were collected for laboratory examination and, in addition, composite soil samples, of the top six inches, were taken from areas of particular interest.

91. The main part of the laboratory work consisted in standardising, and applying to sisal leaves, the rapid chemical tissue tests which have been developed at the Long Aston Research Station, University of Bristol ; but I am indebted to Miss Alexander for the routine analyses of the soil samples and to Dr. Birch for the soil phosphate determinations.

92. The field work and tissue tests were carried out during May, June and July, and, consequently, it was impossible to obtain sufficient data in the time to enable any definite conclusions to be reached. The following are, however, the main indications yielded by a study of the composition of the sisal leaves, as revealed by tissue tests, and the nutrient status of the soils. A full report on this survey has already been presented in November, 1948.

(a) *Banding disease.* Further evidence was obtained that this disease is associated with a potassium deficiency in the plant. Tissue tests invariably showed abnormally low potassium contents in leaves from diseased plants ; and it was found that the potassium content of the plant (and the incidence of the disease) were positively correlated with the ratio of exchangeable potassium to the nitrogen in the soil though *not* with the absolute amount of exchangeable potassium.

(b) *Chlorotic leaves.* This condition was found to be associated with low nitrogen contents in the leaves and there appears to be some evidence that it is rather directly related to the amount of nitrogen in the soil.

(c) *Curling, purpling, and withering of leaf tips.* Much contradictory evidence was obtained in attempting to relate this disease with phosphate deficiency in the leaf. It seems possible that more than one factor may be at work in this type of disease and that phosphorus may be only one of the factors. During this work it was found that an extraordinarily close correlation existed between the amount of phosphate in the leaf and the adsorbed phosphate in the soil.

(d) *Chlorotic mottling on leaves.* These symptoms were invariably observed on acid soils and were accompanied by abnormally low calcium contents in the leaves. The correlation between calcium content of leaves and exchangeable calcium in the soil is close, and consequently it is probable that the symptoms are those of calcium deficiency. There are some indications that excess manganese may play a part in severe cases of the disease.

(e) *Bole rot.* This disease is probably a problem for the mycologist, but it is interesting to note that its symptoms appeared to be influenced by the calcium status of the plant.

SOIL SURVEY AT SHINYANGA—I. A. Black

93. During the first half of October, a rapid survey of soils in two of the experimental plots of the E.A. Tsetse Research Organisation at Shinyanga was carried out. The object of the survey was to find, if possible, acres of similar soil types within experimental blocks which had been (a) protected from fire for 15 years and (b) regularly burned for a like period. In the event of suitable areas being found, it was proposed to establish field experiments to study the effects of regular burning and fire exclusion on the fertility of soils of different types.

94. The observations made during this survey have already been reported in detail (October, 1948), but the main conclusion reached was that it would be extremely difficult to find comparable experimental sites, representing all the soil types, in both blocks, on account of the extreme variability of the soils. It was, however, thought that suitable sites could be found on the red earths and the heavy black clays (*Mbuga*).

PHOSPHATE FRACTIONATE IN SOME EAST AFRICAN SOILS—H. F. Birch

95. With tropical soils no satisfactory method has yet been found whereby the available phosphate status can be determined analytically, and a true indication of the response to phosphate fertilisers obtained. Extraction with dilute acid, such as in Truog's method, has been

widely used, but the results obtained cannot always be correlated with field trials. From examination of papers on the subject published in other countries, it appeared that a better chance of correlating laboratory and field data would be obtained by estimating the adsorbed, water-soluble, and acid-soluble phosphates, since these forms seem to have separate effects in plant nutrition. " Flush " phosphate, the most easily available portions of both acid-soluble and adsorbed phosphate, as described by Arnold (1), was also investigated.

96. The first step was to try out the extracting solutions used by several workers, and to find how closely the results could be correlated with field experiments which were being conducted by the Fertiliser Experiments unit. Table I gives the solutions used and the corresponding references to the literature.

TABLE I

	Extracting Solution	pH	Soil Solution Ratio	Forms Extracted	Authority
A.	0.5 N NH_4F neutral	7	1:50	Adsorbed	Bray & Kurtz (2)
B.	0.5 N NH_4F in 0.1 N HCl	3.7	1:50	Adsorbed and acid-soluble	
C.	0.03 N. NH_4F 0.1 N. HCl	1.8	1:10	Acid-soluble, adsorbed and flush	
D.	0.03 N NH_4F 0.025 N HCl	3.0	1:10	Adsorbed and flush	Arnold (1)
E.	0.025 N HCl 0.024 N CH_3COONH_4	3.0	1:10	Flush	

NOTE: (1) Solution A is used on NH_4- saturated soils.

(2) With B, the soil is first shaken with the hydrochloric acid, then solid ammonium fluoride is added to make the solution 0.5 N and the shaking continued.

(3) B—A=acid-soluble phosphate, according to Bray and Kurtz. The nature of the acid-soluble phosphate is not defined.

(4) C—D=acid-soluble phosphate, according to Arnold.

(5) D—E=adsorbed phosphate, according to Arnold.

(6) E=the most easily available portions of both acid-soluble and adsorbed phosphate.

Acid-soluble phosphate was also determined by extraction with 0.1 N HCl, in order to give a comparison with B-A, and water-soluble phosphate was estimated by the contact equilibrium technique described by Burd (3).

97. Four soils from each of ten fertiliser experiment sites were analysed for acid-soluble, water-soluble, adsorbed, and acid-soluble plus adsorbed phosphate. Although little analytical data (apart from phosphates) is, as yet, available for these soils, they are, on the whole, fairly uniform in the sense that none of them is markedly acidic, calcareous, or contains any appreciable quantity of free iron oxide, nor is there much variation amongst them in their mechanical analysis.

98. The best correlation between crop yield following phosphate application (i.e. increase or otherwise in yield over control) and the various soil phosphate fractions was found with the phosphate extracter by 0.5N NH_4F in 0.1N HCl, that is, absorbed plus acid-soluble phosphate. The correlation between the ten observations was significant at the 0.05 level, and the corresponding regression equation was :

$$Y = -0.33\,x + 81.$$

When $\bar{Y}$ (estimated increase in yield over control) = 0, then x (phosphate extracted with NH_4F in HCl) = 250. This fixes approximately the amount of acid-soluble plus adsorbed phosphate above which, in these soils, no increase in crop yield is to be expected on the application of soluble phosphates.

99. These were the only soil samples available from field experiments in which the crop response to phosphatic fertilisers was known, but further experimental evidence was obtained from the phosphate content of sisal leaves compared with that of the soils in which they had grown. A number of sisal leaves were analysed by Dr. Black of this Department by tissue test methods, and the phosphate in the corresponding soils was fractionated by the methods described. Very significant correlations were obtained between leaf phosphate and the water-soluble, adsorbed, and acid-soluble plus adsorbed phosphate in the soil, but no correlation was found between leaf phosphate and acid-soluble phosphate.

100. In order to find whether any relationship exists between these phosphate fractions, two sets of soils, one lateritic and the other calcareous, were examined. The lateritic group consisted of thirty-five soils which were mainly acidic and contained appreciable amounts of free iron oxide, while the calcareous group of thirteen soils were all rich in exchangeable calcium, several of them containing free calcium carbonate. Positive and very significant correlations were found between the acid-soluble, adsorbed, and water-soluble forms, and between these forms and the acid-soluble plus adsorbed phosphate (determined together in one extraction). In no instance, however, did the sum of the acid-soluble and adsorbed forms determined separately (using 0.1N HCl and 0.5 NH_4F respectively) equal the values obtained when these two forms were determined together using a 0.5N NH_4F solution in 0.1N HCl. This discrepancy was particularly noticeable with acid-soils rich in iron oxides, and has been found to be due, in all probability, to the fact that hydrochloric acid and ammonium fluoride together extract efficiently a form of adsorbed phosphate which is not extracted with neutral ammonium fluoride, and is extractable only to a slight extent with 0.1N hydrochloric acid alone.

101. This investigation showed the importance of the pH value of the ammonium fluoride-hydrochloric acid solution, and it was noticed that neither Arnold's method nor that of Bray and Kurtz had a very wide range of acidity in the extracting solution. Their extractions are summarised in the table below.

Extracting Solution	pH.	Forms of P extracted.
Bray and Kurtz		
A. 0.5N NH_4F	7	adsorbed
B. 0.5N NH_4F in 0.1N HCl	3.7	acid-soluble and adsorbed
Arnold.		
C. 0.03 NH_4F in 0.IN HCl	1.8	acid-Soluble, adsorbed flush.
D. 0.03 N NH_4F in 0.025 N HCl	3.0	adsorbed, flush
E. 0.024 N CH_3COONH_4 in 0.025 N HCl.	3.0	flush

102. It seemed desirable to have a range of extracting solutions from pH 1.8 to pH 7 in order to obtain better fractionation of the phosphate, but it was found that 0.5N NH_4F is too highly buffered to be acidified to pH 1.8. However, a few test extractions showed that 0.1N NH_4F is almost as effective as the 0.5N soluition in extracting adsorbed forms of phosphate, and it has the advantage that solutions with a wide range of pH values may readily be prepared from it.

103. The following extraction procedure is suggested as being more suitable for tropical soils :—

Extracting Solution	PH	Forms of P Extracted
F. in 0.1 N HCl	1.7	acid-soluble and adsorbed
G. 0. 1N NH_4F in 0.025 N HCl	3.5	see text below
H. 0.1 N NH_4F	7.0	adsorbed

Water-soluble and acid-soluble phosphate should also be determined, water-soluble by the contact equilibrium technique of Burd (3) and acid-soluble by extraction with 0.1N HCl. In all extractions a 1:50 soil:solution ratio is advocated.

104. The G. extraction at pH 3.5 gives an indication of the forms of phosphate which have been extracted. When F-G is very low, or zero, then G is a measure of two forms of adsorbed phosphate, namely that extractable with neutral NH_4F (H) and that extractable with acidified ammonium fluoride (G-H). When F-G is positive the figure refers to acid-soluble phosphate derived from calcium phosphate. When

F-G is about equal to the figure obtained by extraction with 0.1N HC1 it may be inferred that G is a measure of adsorbed forms only ; but when F-G is less than the figure with 0.1N NC1 it is likely that G is extracting some acid-soluble phosphate (derived from calcium phosphate) in addition to adsorbed forms.

References

1. Arnold, C. Y. 1947. *Soil Sci.* 64: 101—111.

2. Bray, R. H. and Kurtz, L. T. 1945. *Soil Sci.* 59: 39—45.

3. Burd, J. S. 1948. *Soil Sci.* 65: 227—249.

FERTILISER SCHEME, 1948

Staff

L. R. Doughty	*Officer-in-Charge*
D. W. Gourlay	*Field Experimentalist*
T. Graham	*Field Assistant*
J. D. Roberts	" "
W. J. L. Arthur-Worsop	" "
P. H. Hosegood	" "
H. F. Birch	*Chemist*
I. W. M. A. Black	*Chemist*
Mrs. M. H. Doughty	*Part-time stenographer*

105. When the Cinchona Research Scheme was closed down in August, 1947, it was decided that its members should work on the basic and technological problems involved in the possible use of fertilisers in building up and maintaining fertility of the soil in some of the more densely populated parts of East Africa. After discussions in the territories, numerous field experiments were laid down, mostly in the area round the eastern shores of Lake Victoria and thereafter extended to other parts of East Africa as staff became available.

106. Close collaboration exists with the Kenya Highlands Fertiliser Scheme and joint headquarters are in use at Eldoret.

SITES OF EXPERIMENTS

107. The programme of work was designed to study in the field, and in the laboratory, the nutrient status of as wide a selection of East African soils as possible, with emphasis in the first place on the phosphate requirements. Whilst food crops are considered to be of primary importance, all crops in the rotation, where such is practised, are to be studied. Attempts were made to secure wherever possible, land that had been under cultivation for some time and to lay down experiments on native-owned plots cultivated in accordance with local practice. In most cases, however, this was not feasible, since there is considerable prejudice amongst the Africans against interference, and a marked feeling that experiments might lead to the permanent loss of land.

108. In the Lake Province of Tanganyika Mr. Prentice of the Empire Cotton Growing Corporation, who was then in charge of the Agricultural Station at Ukiriguru, arranged for his recorders to secure for our use plots of land in reasonably proximity to the district cotton extension plots, and the plot holders agreed to do the necessary work on payment of a nominal fee plus the produce of the plots. In addition to these district plots land was made available for our use on the experimental farms at Ukiriguru, Lubaga, and Butulwa.

109. In the Nyanza Province of Kenya plots were placed at our disposal by the Department of Agriculture both on their farms and in the districts, and in addition a number of missions co-operated in the work. Land was also made available at the Veterinary Training Centre at Sangalo. Several native owners were willing to co-operate, but owing to difficulty of access it was possible to use only one of these plots.

110. In the Eastern Province of Uganda, with the help of the District Commissioner, Mbale, agreement was reached with 17 chiefs and three missions for the use of plots, but on account of labour and other difficulties, only 16 experiments were planted.

FERTILISER DRESSINGS AND METHODS OF APPLICATION

The basic fertiliser dressings were :—

	Fertiliser lbs. per acre	cwts. total nutrient per acre
Sulphate of ammonia	107	0.2N
Triple superphosphate	108	0.2P
Soda-phosphate 22%	223	0.2P
Uganda Rock Phosphate	202	0.2P
Muriate of potash	54	0.2K
Kraal manure or compost	—	5 tons
Ground limestone		1.5 tons

111. In the first experiments planted all the fertilisers were applied directly to the holes immediately after planting, but this had a very adverse effect on germination, sulphate of ammonia in particular having a very marked killing power. Later the fertilisers were applied in a ring round the holes, 3-4 inches away from the plants, and raked in. Even this method appeared to influence germination in some experiments. In later experiments the fertilisers were drilled alongside the rows of plants 3-4 inches away from the planting rows and then raked in ; there is no evidence of any damage by this method. For the short rains crops the phosphates were drilled at about 3 inches below ground level before planting and the seed planted above the phosphate. When sulphate of ammonia was used it was applied as a top dressing after the seed had germinated.

DESIGN AND METHOD OF EXPERIMENTATION

112. The experimental designs used during 1947-48 were :—

Type 1a. A 3^3 design, using sulphate of ammonia, superphosphate and muriate of potash each at three rates, 0, 1x and 2x the basic dressing.

Type 2a. A 2^3 design using N, P, and K. There were four blocks at eight plots each at each site for these experiments. On two blocks super-phosphate was used and on two blocks soda-phosphate.

Type 3. A 4 x 2^3 experiment comparing three types of phosphate rock, soda and super with none and with all combinations of the fertilisers N, K, and organic. Only three of these experiments were used, all in the Lake Province, Tanganyika Territory.

Type 5. This experiment is a comparison between soda and super-phosphate at single and double the basic dressings with and without the addition of a basic dressing of nitrogen.

Type G. A comparison between rock, soda and super-phosphate at 1x and 2x the basic dressing for soda and super, and 2x and 4x the basic dressing in the case of rock-phosphate together with all combinations of N. and lime. In this last series potash was left out after consultation with the soil chemists of the Department of Agriculture in Uganda and Kenya.

113. A total of 63 experiments were laid down with maize, sorghum, groundnuts, mixed millets, sweet potatoes and *Eleusine coracana* (Wimbi) : 16 of these were failures. In addition, 23 micro-plot experiments were planted, as near as possible to the main experiments and 18 of these were harvested. The plant population aimed at with the large grain crops was about 10,000 per acre, i.e. at planting distances 4 by 1 feet. With wimbi, the seed was drilled in rows one foot apart except in two experiments in Nyanza where the rows were two feet apart. Groundnuts were spaced at 1 by 1 foot.

114. Before the fertilisers were applied, soil samples were taken on all experimental areas at 0-6 inch depth at four points within each plot, the samples being mixed and a composite prepared for each block of the experimental area. Samples were also taken of the thoroughly mixed bulks of soda- and rock-phosphate.

115. Owing to the wide distribution of the experimental sites, it was not feasible to harvest, thresh and weigh all the produce from each experiment. Accordingly small samples were taken from each plot—ten maize cobs, thirty heads of mixed millets, four pounds of wimbi and sorghum heads, and four pounds of groundnuts. The tendency to pick large cobs or heads of maize and mixed millets rendered the method unsatisfactory for these, and a satisfactory technique for random sampling has yet to be found.

RESULTS

LAKE PROVINCE, TANGANYIKA

MAIZE

116. Seven experiments were carried out with the quick-maturing maize Katumbili, four being on lake-shore sand, one on a soil transi-

tional between red sandy loam and black clay, and two on black clay. In the first five of these, germination was adversely affected by the nitrogen dressing and the final yields were influenced by the reduction in stand. One trial on lake-shore sand did give marked increases in yield, but, apart from this, there was a general reduction in yield due to nitrogen and no effect of either soda or super-phosphate. On the black clay nitrogen did not affect germination, but there was no effect on yield of nitrogen, soda phosphate, or super.

MIXED MILLETS

117. Thirteen experiments were planted with mixed millets, three parts bulrush millet to one part "wiru" sorghum. Only seven of these were harvested, and, owing to the very variable stands and subsequent damage by birds, the data from these experiments is of little value. Nitrogen appears to have improved development of the plants, but no definite information has been obtained with this crop.

SORGHUM

118. Eight sorghum trials were laid down, on calcareous grey loam, red sandy loam and black clay. The calcareous grey loam gives high yields with good rains, and it was not surprising that no effect of fertilisers was observed, since the mean yields ranged from 800 to 1,000 lb. per acre. On the red sandy loam there were responses to super-phosphate and also to nitrogen and organic manure.

NYANZA PROVINCE, KENYA, & EASTERN PROVINCE, UGANDA

MAIZE

119. The mean yields obtained from eight experiments with maize are set out in Table I for the phosphate and nitrogen treatments averages over the lime treatments. Lime throughout showed no effect so is not shown separately.

TABLE I. Mean yield of maize in bags (200 lb.) per acre. (8 experiments).

			Treatments. (Rock-phos)		(soda-phos)		(super)	
			rr	rrrr	s	ss	p	pp
Without	n	13.95	14.38	13.34	15.82	16.84	15.77	17.24
With	n	16.25	14.08	17.62	17.68	18.45	17.69	18.92
			Relative responses as % control					
Without	n	100	103	96	113	121	113	124
With	n	116	101	126	127	132	127	136

120. The error in these experiments, each a single replication, is high and therefore the comparisons for phosphate, based on yields from four plots in each experiment, do not reach levels required for significance. The nitrogen effect does (+ 1.96 bags per acre $\pm$ 0.58). In only one experiment, at Kaimosi, was there a negative response to nitrogen, and this experiment was badly damaged by hail. The experiments showing the biggest phosphate responses are on the foot slopes of Mount Elgon in Kitosh and around Bukura in the South of North Nyanza. The average yields of maize are high throughout and with yields of this order large responses would not be expected.

WIMBI

121. Ten experiments were harvested satisfactorily, one in North and one in Central Nyanza and eight in the Eastern Province of Uganda. The mean yields obtained from ten experiments combined are set out in Table II.

TABLE II. Mean yields of wimbi grain—lb. per acre. 10 experiments.

		Treatments.					
		rr	rrrr	s	ss	p	pp
Without n	891	828	836	921	973	918	1053
With n	1004	1165	1039	1171	1153	1113	1249
		Relative responses as % of control.					
Without n	100	93	94	103	109	103	118
With n	113	131	117	131	129	125	140

122. In this series of experiments again the error is high and the only significant effect is that of nitrogen (+ 198 + 25 lb.). On only one experiment is the influence of phosphates very marked and, incidentally, in this experiment the nitrogen effect (+ 367 lb.) barely reaches significances. This is at Amakura in the hills on the Uganda border. The soil on this plot is a light sandy loam and has been in cultivation for a number of years. The effect of phosphates in hastening ripening was so great that this experiment had to be harvested at two different times.

123. On two experiments there was a fairly marked response to lime, at Busaba and Kachonga. In neither case did the effect reach the limits for significance but this observation will be borne in mind during the continuation of these trials.

SORGHUM

124. Of the eight trials of this crop three had to be replanted owing to poor germination at the first planting, and three had to be abandoned for various reasons. On preliminary examination of the results the lack of response to nitrogen was attributed to loss of the nitrogen during the early period of growth of the first crop, but as the two experiments, which had grown away at the first planting, gave a similar result, all the figures have been combined. None of the differences reach levels required for significance.

TABLE III. Mean yields of Sorghum grain in lb. per acre. 5 experiments.

		Treatments.					
		rr	rrrr	s	ss	p	pp
Without n	879	946	664	1013	1235	1040	1134
With n	778	939	832	939	980	1147	1235
		Relative responses as % of control.					
Without n	100	108	76	115	141	118	129
With n	89	107	95	107	112	131	141

125. The nitrogen apparently did not affect the stand of plants in these experiments. The lack of response to nitrogen needs further investigation as observations during the growing period on these experiments seemed to indicate a very marked response to super and soda-phosphate in combination with nitrogen, which is not apparent in the yields.

GROUNDNUTS

126. Only two out of the three experiments with groundnuts were harvested. Yields were very low, 325 lb. shelled nuts per acre, and there were no responses to fertilisers.

MICROPLOTS

127. Two types of microplots experiments were used. One series was a 3x3x3 experiment in three blocks of nine plots to test N, P (super-phosphate) and K each at three levels and the other type was a 3x3x3x3 experiment with nine blocks of nine plots each including the above fertilisers and in addition lime. The dressings of fertilisers used in the microplot experiments are equivalent to 0, 3 and 6 cwts. of sulphate of ammonia per acre (0.66 and 1.32 cwts. N. per acre), 0, 1 and 2 cwts. per acre of triple super-phosphate (0.48 and 0.96 cwts. P_2O_5) and 0, 1 and 2 cwts. per acre muriate of potash.

128. The results of these microplot experiments indicate that during the early stages of growth of maize, the young plants, judged on their fresh weight yields, can only take advantage of additional phosphate and nitrogen added to the soil when these are present together, the effects of either one or the other alone being very limited. Added potash has no effect on development in the early stages in these areas and lime appears to have a slight depressing effect on growth.

129. There is, however, little correlation between the microplot results and those from the full scale experiments. These differences may possibly be explained by the difference in time and season existing during the early stages of the development of the crops. Had the microplots been planted at the same time as the major experiments there may have been a closer correlation between the results. We cannot attempt to correlate the microplot findings with the soil analyses yet as many of the soil samples have not yet been dealt with.

GERMINATION TESTS

130. To confirm or refute the supposed influence of soda-phosphate on germination, six microplot trials were laid down. Four of these were done by Agricultural Officers of the Kenya Department and two by the Fertiliser team. The Nyanza trials were carried out early in the season and watering proved a problem : one was a failure. The Uganda trial was washed out by a very heavy downpour, so that only four were satisfactory. Fertilisers were either broadcast or placed immediately over the seed at planting in increasing dressings from a single basic dressing up to eight times the basic dressing, which with soda-phosphate is 16.6 cwts. per acre. The crops included in the trial were cotton, maize, groundnuts, wheat, two types of sorghum and two types of millet. The comparative effects on germination averaged over all crops are summarised in Table IV.

131. Comparison of the effect on germination of applying sulphate of ammonia and phosphatic fertilisers in contact with seed and broadcast.

Table IV

N	Rate per acre cwts. Super,	Soda.	Mean % germination, all crops combined. Broadcast Super	Soda.	Placed Super	Soda.
.5	nil	nil		42.0		38.0
.5	0.96	2.07	39.25	42.25	39.00	36.25
.5	1.92	4.14	43.75	40.00	39.25	37.25
.5	3.85	8.30	46.50	41.00	37.75	32.00
.5	7.71	16.60	40.25	38.00	35.00	27.50

132. It will be seen that the phosphates and nitrogen placed in contact with the seed adversely affect germination to a slight extent, soda-phosphate more than super, especially in the higher dressings. The biggest depressing effect on the soda-phosphate was obtained at Ukiriguru in the Lake Province of Tanganyika.

DISCUSSION

133. The usual hazards of field experimentation have left their mark on the first year's experiments. The weather at planting time played some part in the poor results obtained in the Lake Province, Tanganyika, and as noted in earlier paragraphs many experiments had to be replanted and stands were very variable.

134. In the Nyanza and Eastern Province of Uganda planting had also to be delayed and some experiments had to be replanted. There is in consequence a very high variability in the yield of plots and as the majority of the experiments were single replications the error is very high. The mean yields from the experiments as a whole, with the exception of mixed millets, were high.

135. Phosphate responses are not big and do not reach the levels required for significance. There is nevertheless sufficient uniformity in the results to indicate that in the Nyanza and Eastern Province of Uganda at least, maize and sorghum will respond to phosphate treatment and that the response to soda and super-phosphate in this series of experiments is about the same. Rock-phosphate has given very variable results, the overall effect being neglible.

136. The biggest response to phosphate applied to maize has been obtained at Bukura in North Nyanza, and another marked response was obtained with sorghum on a similar soil at Iwinda, not far to the west of Bukura and on the same ridge. On three experiments with maize in Kitosh, round Kimiliki, fairly high responses were also obtained.

137. Wimbi (*eleusine*) showed much lower responses to phosphates, the only striking result being obtained at Amakura on the Nyanza-Uganda boundary.

138. In the Lake Province of Tanganyika, maize shows no response to phosphates on the Lake shore sands or black clay soils. Sorghum shows no response on the calcareous grey loams round Shinyanga but appears to respond on the red sandy loams.

139. In general it appears that on soils of the red earth type derived from granite responses to phosphates may be expected, particularly with the large grain crops, but at the same time these soils are capable of giving fairly high to high yields, under an adequate rainfall, without added phosphate.

140. In Kitosh, a region with a good rainfall, land under cultivation with maize for many years still gives yields in the region of 15 bags to the acre in a good year, although the experimental results here show a response to added phosphate. In the Lake Province of Tanganyika the rainfall is low and variable and therefore the determining factor in production.

141. Sorghum and Eleusine (wimbi) show less response than maize in terms of food produced. Nitrogen is effective in increasing yield with maize and wimbi, but sorghum, at least during the past season in Nyanza and Eastern Province, Uganda, does not respond. The mean effect of nitrogen on the maize experiments in these areas is 1.96 bags per acre and on wimbi an increase of 222 lb. per acre, averaged over all phosphate treatments. The effect of nitrogen is additive to that of phosphate, there is little or no interaction.

142. The responses to fertilisers shown by this first year's experiments indicate that with native grown crops, the extra grain is only obtained at considerable expense. At the rate of fertiliser application in these experiments the mean increase in yield of maize is under five bags per acre for an increased expenditure of about Shs. 170/- on fertilisers when super-phosphate and sulphate of ammonia are used ; with soda-phosphate the additional cost is about Shs. 86/- per acre, both figures excluding cost of carriage and application. With wimbi, Shs. 57/- worth of nitrogen results in an increase of some 200 lb. per acre of grain and with the addition of phosphate at basic dressings another 100 lb. per acre of grain at a cost of either Shs. 15/- or Shs. 57/- per acre according to type of phosphate used. A similar total response appears to be obtainable with phosphate alone when sorghum is grown with double basic dressing, i.e. cost Shs. 30/- or Shs. 114/- depending on the fertiliser used.

143. Important as these probable increases are from the point of view of food production it would be a strain on any native producer to provide the necessary cash.

144. The contribution the fertilisers make towards improved general fertility have not been assessed as all the short rains crops failed.

145. Reports by Dr. Black and Dr. Birch on the laboratory work of the scheme are, for convenience, included in the report of the Section for Soil Chemistry.

CLOVE RESEARCH SCHEME—ZANZIBAR

Staff

F. J. Nutman, D.SC., D.I.C.
F. M. L. Sheffield, D.SC.
(*on secondment from Rothamsted*)
R. I. Robb, B.SC.
T. E. C. Robins
E. C. Diekmahns, B.SC.
(*left on appointment to Tanganyika on November 29, 1948*)
W. B. May
(*on secondment from E.A.A.F.R.O.*)

146. The Clove Research Scheme formally started in November, 1947, but not until about sixth months later were facilities and staff reasonably complete. The main object of the Scheme is the investigation of the Sudden-death disease ; and therefore no sectional reports are given, but individual work referred to at an appropriate place in the discussion of the results of the team as a whole.

147. Although the Sudden-death disease has been known for many years, very little published information is available. The first work we undertook was a study by Dr. Nutman and Dr. Sheffield of the disease and its epidemiology in the two islands of Zanzibar and Pemba. The disease produces no specific symptoms prior to the onset of the final phase, which is characterised by a rapid leaf-fall, a sudden wilt, and complete disorganisation of the root system. We have been able to show, however, that slight chlorosis and reduction in the leaf-equipment precedes, often by many months, the final symptoms. The epidemiology of the disease differs in the two islands. In Pemba, where the death rate is at present moderate, it is confined to rather more than 500 separate outbreaks, which vary considerably in size and rate of development, but which all show clearly defined peripheral spread. In Zanzibar, the situation approximates to one outbreak, involving about half the clove-growing area of the island. This we interpret as the result of the fusion of a large number of individual outbreaks. The death rate is demonstrably increasing in both islands and that for Zanzibar approximates reasonably closely to an exponential curve.

148. After full consideration of all possible causes, Nutman and Sheffield have reached the conclusion that only a pathogen could give rise to the observed phenomena : and that of all possible pathogens, a virus seems the most probable. Previous work makes a direct fungal attack most unlikely, but the possibility that a xylem-inhabiting toxin-producing fungus may be responsible is receiving attention.

149. As a result of these findings, a policy of attempted control in the island of Pemba has been suggested in a joint memorandum by Dr. B. A. Keen, F.R.S., Director of E.A.A.F.R.O., and Dr. Nutman. The recommendations therein contained have been reviewed by a Colonial Office Advisory Mission, comprising Mr. F. C. Bawden, F.R.S., Dr. W. J. Hall, Dr. Hubert Martin and Dr. H. H. Storey, F.R.S., C.M.G.

150. In an attempt to find either a diagnostic character of the disease or some indication of a possible pathogen, Dr. Sheffield has made a detailed study of the histology and anatomy of apparently healthy trees and of trees expected to die from Sudden-death. She found the clove to differ from the average dictotyledon in a number of ways, and that some of these abnormalities are ones usually associated with a pathological condition. The only differences found between healthy and diseased cloves were that these abnormalities occurred earlier and were accentuated in the latter. This evidence alone might suggest that the disease is merely the culmination of a long period of adverse conditions, but the epidemiological evidence suggests very strongly that this explanation is incorrect. Of the possible groups of pathogens, only fungi have been found. These occur in small quantities on the roots of both healthy and suspect trees.

151. The testing of a pathogenic hypothesis presents great difficulties with refractory material such as the clove for until Mr. May undertook a study of grafting methods in December, 1948, it had never, so far as we have been able to ascertain, been successfully grafted. Mr. May's results have shown one reason for this, since not only have both stock and scion to be vigorously growing and maintained for 3-4 months under conditions of heavy shade and high humidity, but any form of sealing the graft results in complete failure. The only successful grafts have been those where the union has been kept covered with damp moss only, and 1.6% of successful unions have been achieved by this method. Only approach grafts give a high enough percentage of success to be of any practical value. A promising line for transmission work has been opened by the development of leaf grafts. The leaf petiole with leaf attached is inserted beneath the bark of the stock. Strong pressure applied by a spring clip appears, for some unknown reason, to accelerate union and 17% success has been recorded. True union with continuity of phloem has been confirmed. All attempts at root grafting have so far failed.

152. Experiments are now in progress where leaves from trees suspected of the disease are grafted to healthy seedlings and also seedlings are being inarched, in the field, to branches from mature trees in the path of the advancing disease. No results are yet available.

153. During the course of the epidemiological studies referred to earlier, a careful search was made for possible vectors; the only one so far found is the scale *Saisettia sp.* which is tended and transported by the red tree ant *Occophylla longinoda*. Dr. Sheffield and Dr. Nutman have worked out in a preliminary manner the interrelationships between the ant and the scale, and as a result have been able to set up a series of transmission experiments in which the ant is induced to transplant scales from suspect material to healthy seedlings; results are awaited.

154. Mrs. Robb has undertaken the difficult and laborious task of transferring scales by hand from diseased material to the expanding cotyledons of healthy seedlings. Very extensive series of transmission experiments are now being set up using this technique.

155. Of secondary importance to the main lines of work outlined above are physiological studies of the clove in health and disease. Dr. Nutman has undertaken this, with assistance in the early stages from Mr. Diekmahns. As might be expected, the physiology of the clove is by no means normal and climatic conditons and the refractory nature of the material make work slow. Attention is being concentrated, in the first instance, on the water relations of the tree and its assimilation rate. The relations between the march of these and external conditions are being worked out and the preliminary results are of some interest, the onset of the disease being associated with marked depression of the photosynthetic rate and moderate depression of the transpiration rate. In this stage the reduction in rate of water loss does not seem to be caused by water shortage. It is apparent that this work must continue for a long time before results of any applicability are likely to be produced.

156. Mr. May is also carrying out a study of the effect of other rootstocks on the clove, with the object of producing an improved type of tree or, possibly, one which is resistant to the disease. Unfortunately the *Eugenia* species so far used, although some callus freely, make no proper union, separate cambiums being formed in both stock and scion. A possible explanation of this is the confusion in which the genus *Eugenia* appears to be : the possibility being that the other stocks are not true Eugenias and incompatible with the clove. If, as has been suggested, the clove is monotypic, the chances of success are but slight.

157. In addition to the lines of work outlined above, some researches of wider applicability have been started. But it is too early to deal with these, even in outline, in an annual report.

158. During the year, visits have been paid by Dr. R. le Pelley, of the Kenya Department of Agriculture, who has helped with the entomological work ; by Mr. A. F. Posnette of the West African Cacao Research Institute, who has submitted a valuable report on the disease ; by Dr. H. C. Pereira of the Kenya Department of Agriculture, who has advised on soil problems ; and by Dr. H. H. Storey, F.R.S., of E.A.A.F.R.O. Dr. B. A. Keen, F.R.S., has been a constant visitor. Visits to the laboratories have also been paid by H.H. the Sultan of Zanzibar and by H.E. the British Resident.

RESEARCH SCHEME ON CLIMATIC DATA IN RELATION TO AGRICULTURE

A. Walter

159. The objectives are : (1) To determine some function of temperature showing a close relationship to the temperature requirements of specific crops. (2) To establish if possible a relation between air temperature and incoming radiation. (3) To determine a function of rainfall which bears some relations to soil moisture.

160. The observations available from the simple climatic observing stations are : (1) Observations of Dry and Wet Bulb temperatures once a day ; (2) observations of Maxima and Minima temperatures ; (3) observations of Daily Rainfall.

161. As hourly observations of radiation were available from the Kabete first order station between 1939 and 1943 preliminary work has been carried out as follows :—

162. The hourly values of temperature were tabulated under ranges of temperature in 1°C intervals. The hourly values were then submitted to harmonic analysis to determine the first three components of the Fourier series. The ratios between the amplitudes of these components and the corresponding ranges were then computed. The object was to show that given the temperature range the diurnal curve could be derived, on the average from observations of Maxima and Minima values only.

163. The results show that the relationship between ranges and each of the amplitudes is very close. It is in consequence possible by integration of the resultant curve for each range of temperature to obtain a measure of the number of degree hours between any given specific times without having recourse to hourly records. For comparisons with incoming radiation integration will be effected between sunrise and sunset.

164. The mean ranges were then compared with the corresponding values of incoming radiation. While on the average there is a close relation between ranges and incoming radiation a detailed examination of individual days revealed tha tlow afternoon vapour pressures appeared to coincide with high radiation values even when temperature ranges were low. The temperature is clearly related to the radiation measures which show much lower values in the cool months of the year.

165. The work of correlating the total of degree hours of temperature between sunrise and sunset, the afternoon vapour pressures and the values of incoming radiation is now in hand.

166. It is well-known that the absorption by water-vapour of certain wave lengths in solar radiation affects the amount of incoming radiation. This will be referred to in greater detail in later reports. In the meantime an empirical relation is being sought from the actual daily observations at Kabete and the work of tabulation is well advanced.

167. Arrangements are also being made to analyse the rainfall returns from as many stations as possible on the Hollerith machines. From the inception of the meteorological service in East Africa rainfall stations have been given a registration number based on a geographical distribution with a view to ultimate analysis on the Hollerith cards. These registration numbers classify stations into 1/10 degree regions so that complete analysis in geographical distribution and altitude is facilitated. By means of the Hollerith cards any function of rainfall dependent on amounts or frequencies which may ultimately be found to bear a relation to the soil moisture curve can be derived.

Printed by the East African Standard Ltd—18510/8/42.